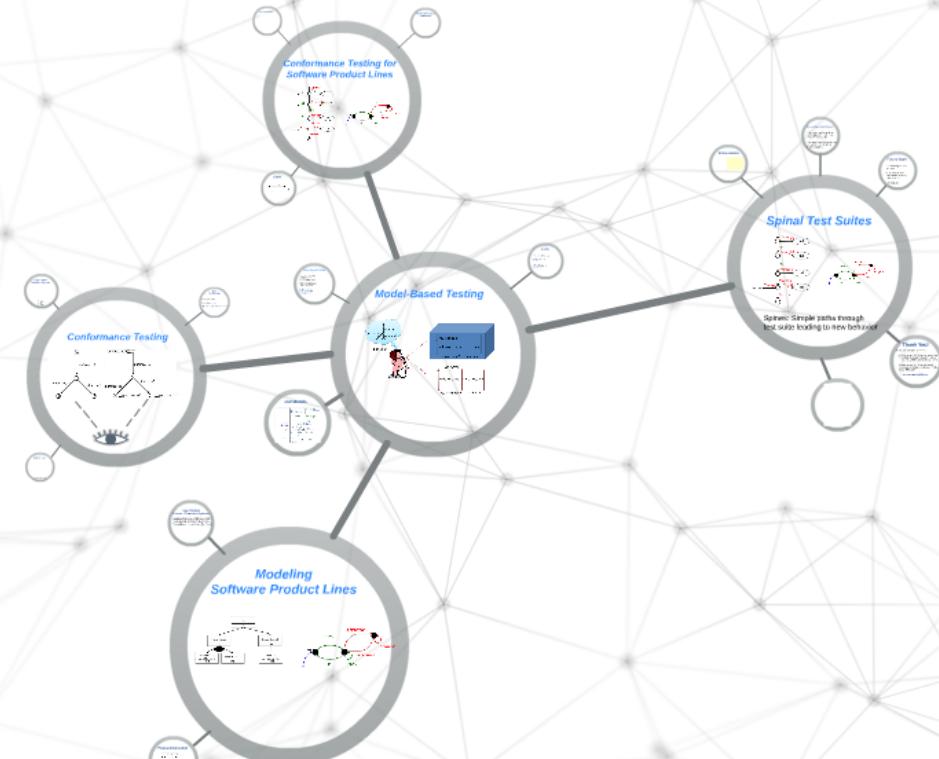


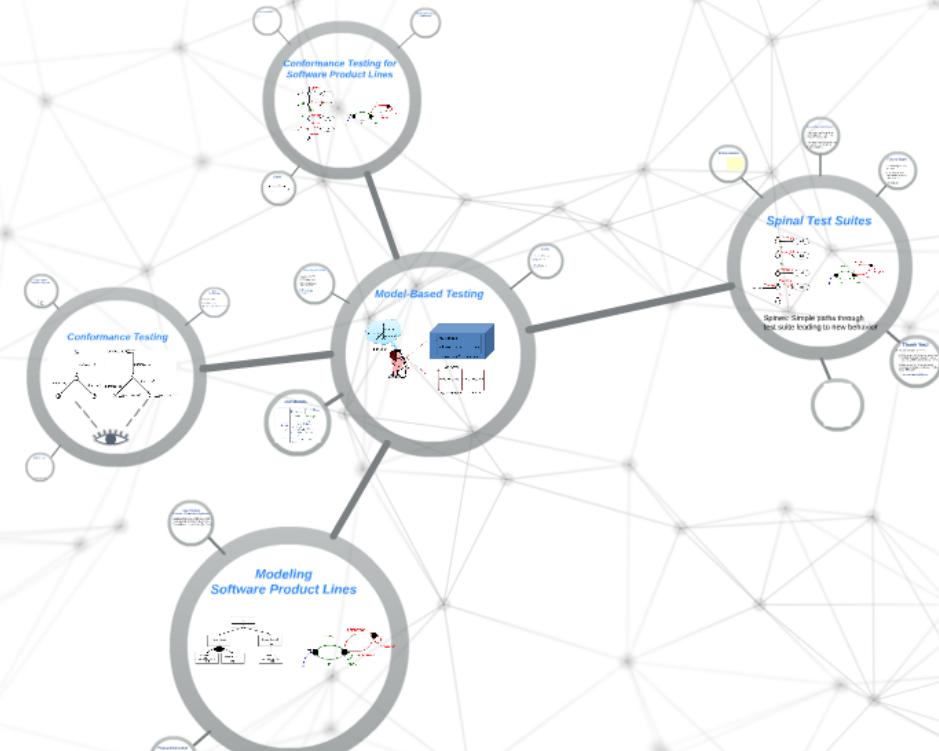
# Spinal Test Suites of Software Product Lines

Harsh Beohar and Mohammad Mousavi  
Halmstad University



# Spinal Test Suites of Software Product Lines

Harsh Beohar and Mohammad Mousavi  
Halmstad University



• Abstractions from reality

• Separating different concerns

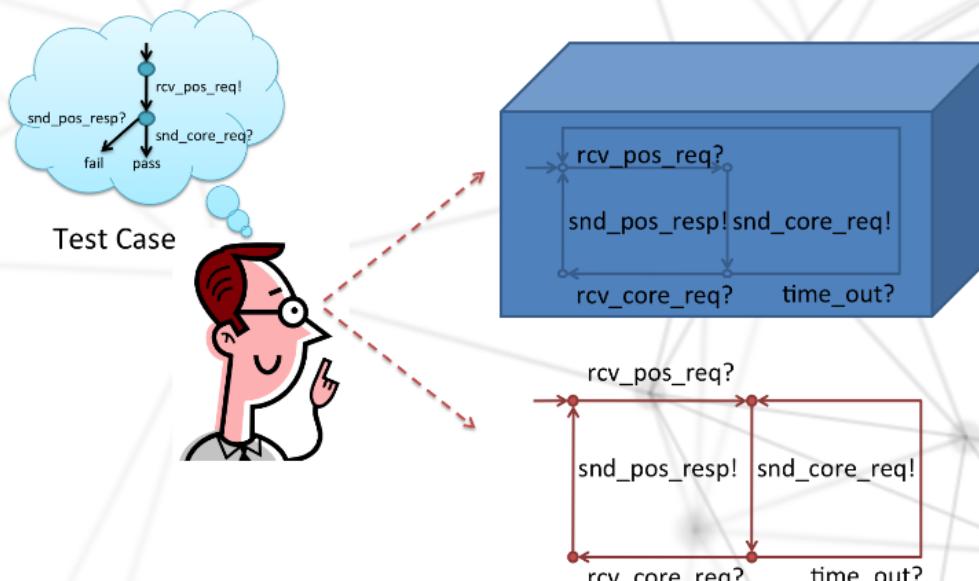


• Approximating system behavior and / or its environment

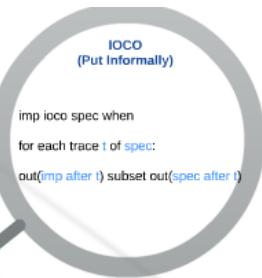
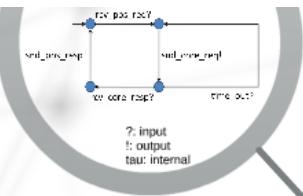
### Model-Based Testing

- Fault: a mistake in the implementation (design, specification)
- Failure: an observably incorrect behavior
- Testing: a planned experiment to turn faults into failures

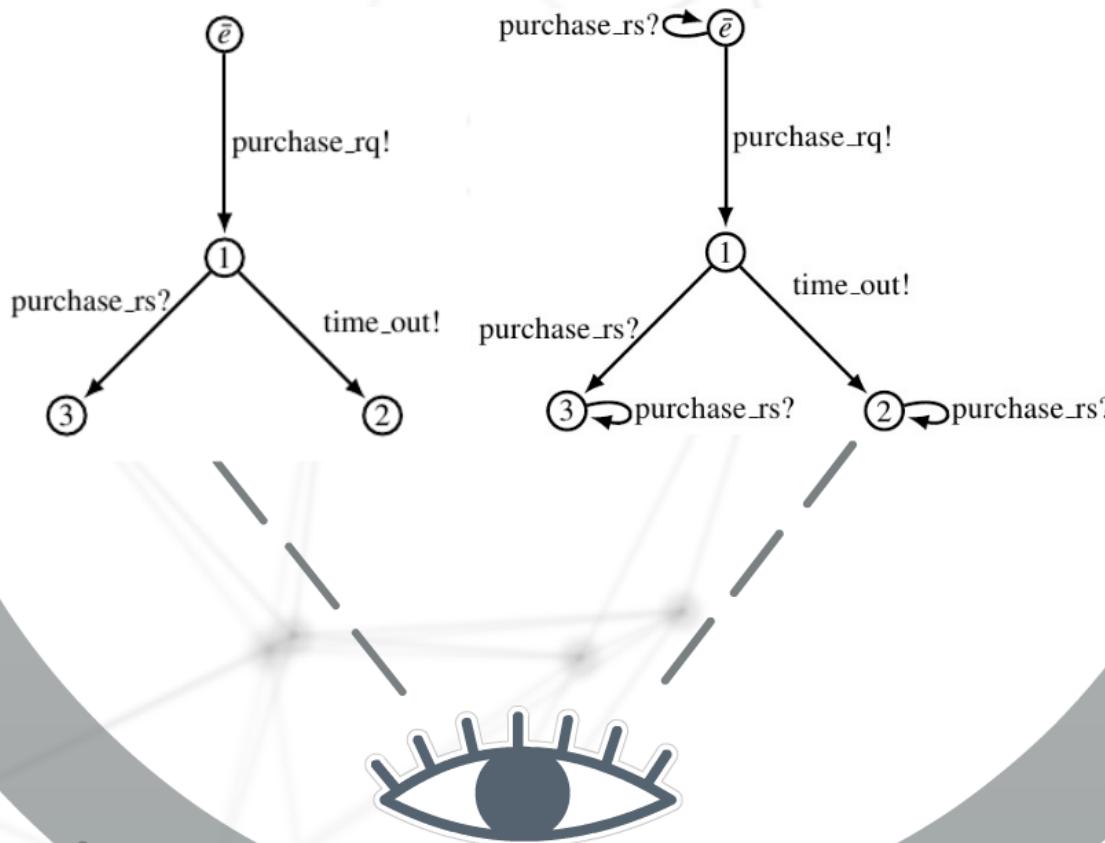
# Model-Based Testing



13



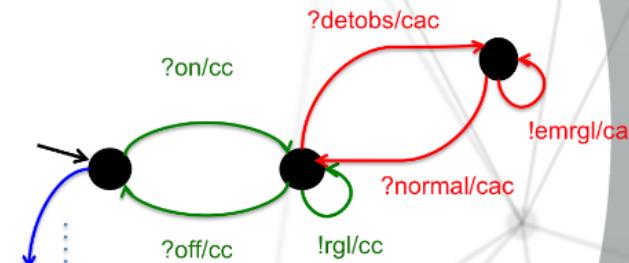
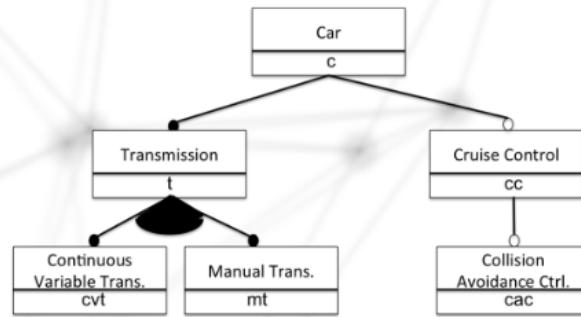
# Conformance Testing



IOCO Test-Cases



# Modeling Software Product Lines

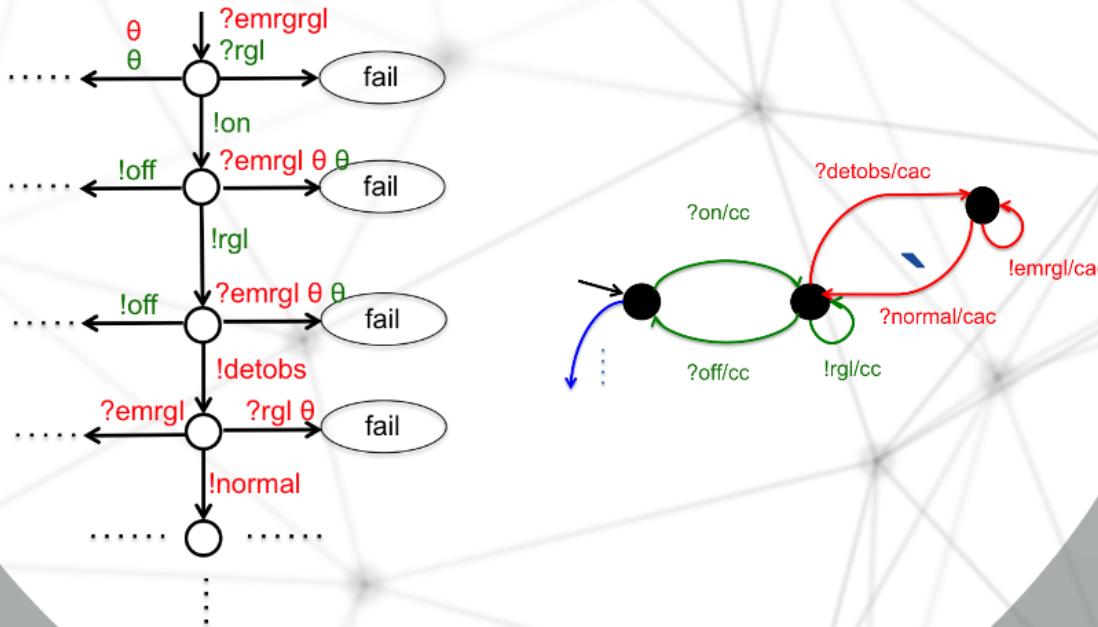


Product Derivation

$$\frac{\pi_1, \lambda \vdash (\gamma(s, a, s') \wedge \varphi)}{\Delta_\varphi(s) \hookrightarrow_{\text{derivation}} \gamma(s, \Delta_\varphi(s'))} \quad (1)$$

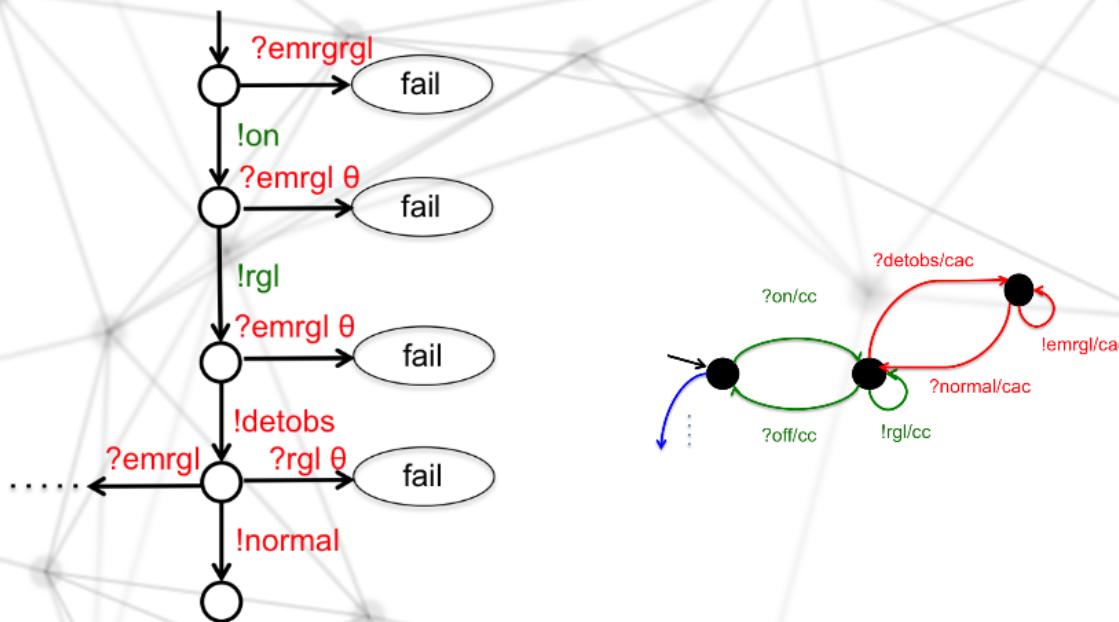
$$\frac{\pi_0, \lambda \vdash (\gamma(s, a, s') \wedge \varphi) \wedge a \in A_0 \cup \{\tau\}}{\Delta_\varphi(s) \xrightarrow{a} \Delta_\varphi(s')} \quad (2)$$

# Conformance Testing for Software Product Lines



Click!

# Spinal Test Suites



Spines: Simple paths through  
test suite leading to new behavior

Thank You!

For more information please see:

- H. Beohar and M.R. Mousavi. Input-Output Conformance Testing Based on Feature Transition Systems. ACM SAC-SVT 2014

• Abstractions from reality

• Separating different concerns

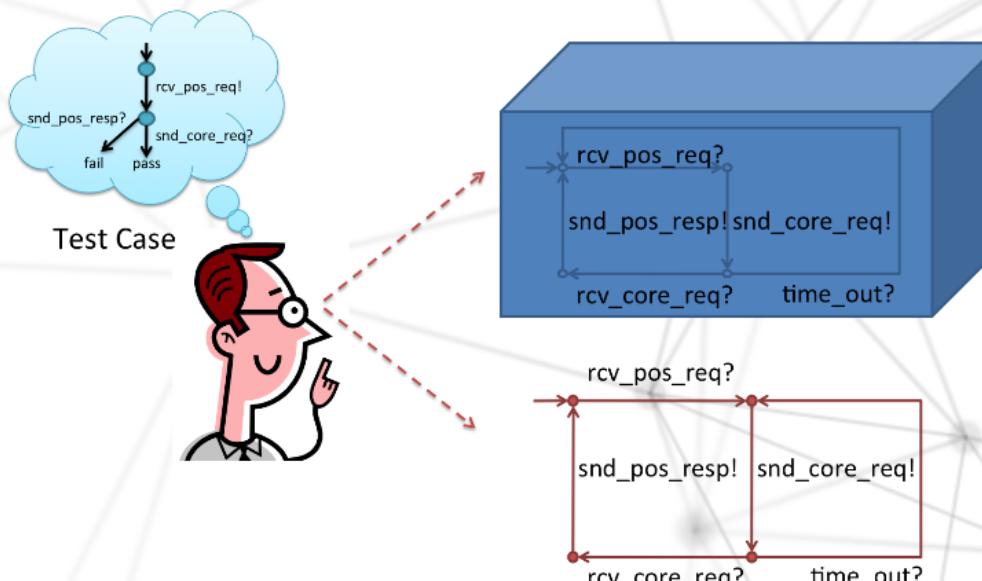


• Approximating system behavior and / or its environment

### Model-Based Testing

- Fault: a mistake in the implementation (design, specification)
- Failure: an observably incorrect behavior
- Testing: a planned experiment to turn faults into failures

# Model-Based Testing

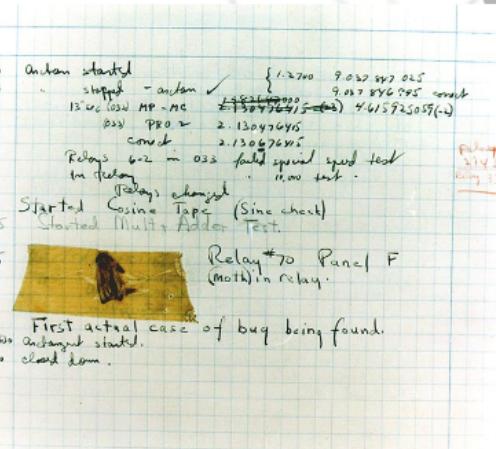


13

# *Model-Based Testing*

- Fault: a mistake in the implementation (design, specification)
- Failure: an observably incorrect behavior
- Testing: a **planned experiment** to turn faults into failures

9/9  
0 5800 Antran started  
1 0000 stopped - antran ✓ { 1.2700 9.032 892 025  
13 026 032 MP-MC 9.037 896 995 (work)  
023 PRO ✓ 2.13097695  
convdc 2.13067695  
Relays 602 in 032 failed open speed test  
in relay 11.000 test.  
[Relays checked]  
1100 Started Cosine Tape (Sine chart)  
1525 Started Multi Adder Test.  
1545 Relay #70 Panel F  
(moth) in relay.  
1550 First actual case of bug being found.  
Antran started.  
closed down.

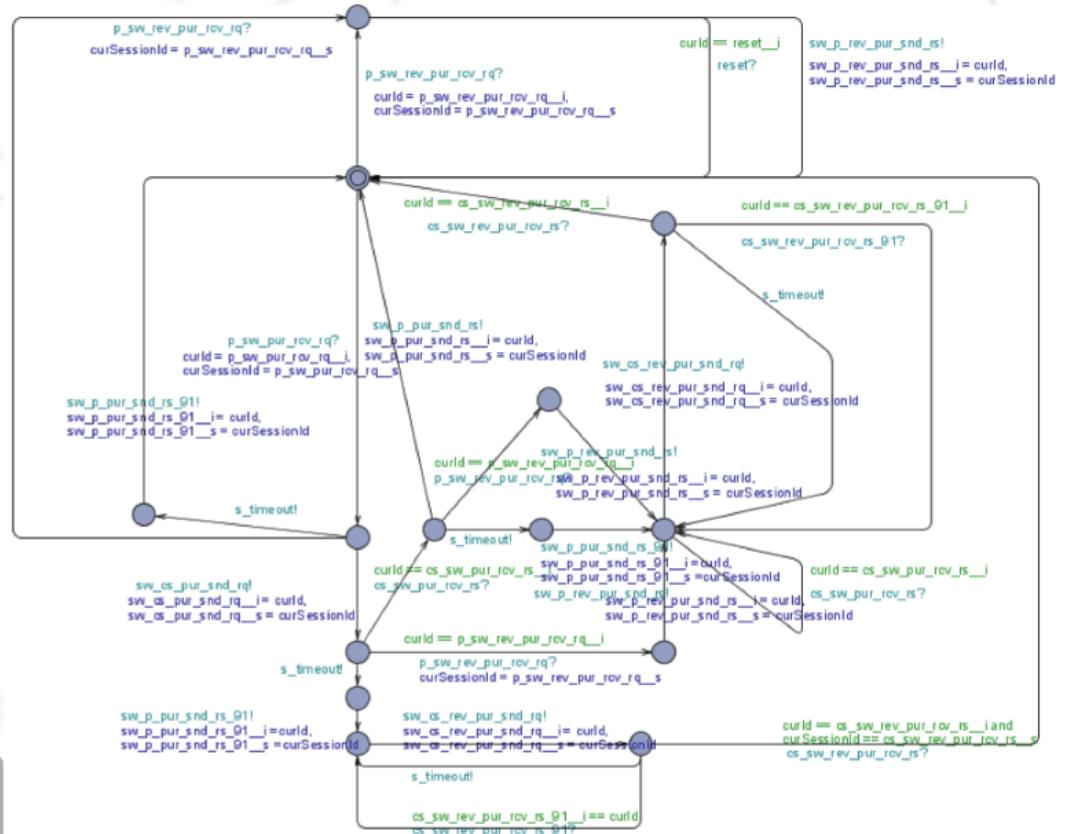


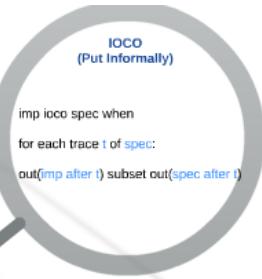
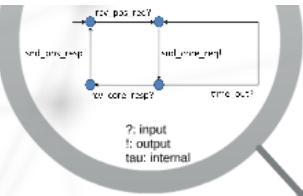
# Models

- Abstractions from reality
- Separating different concerns
- Approximating system behavior and / or its environment

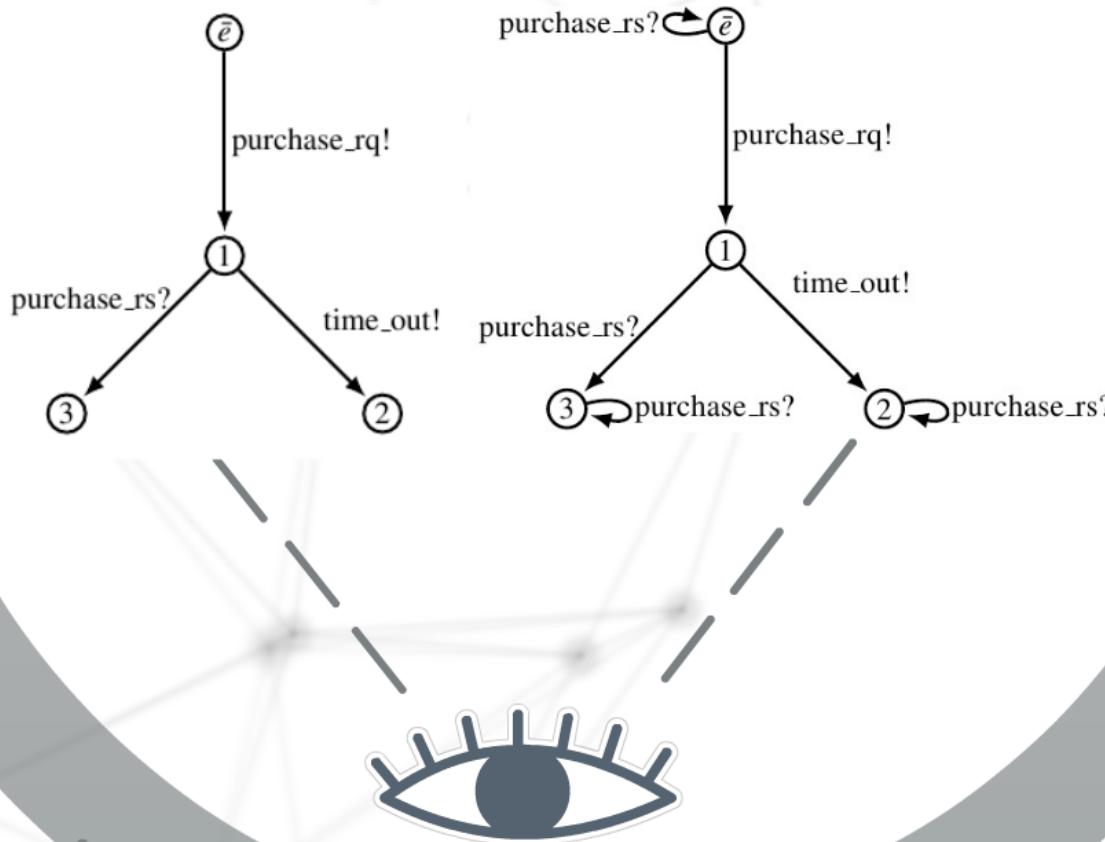


# Our Models





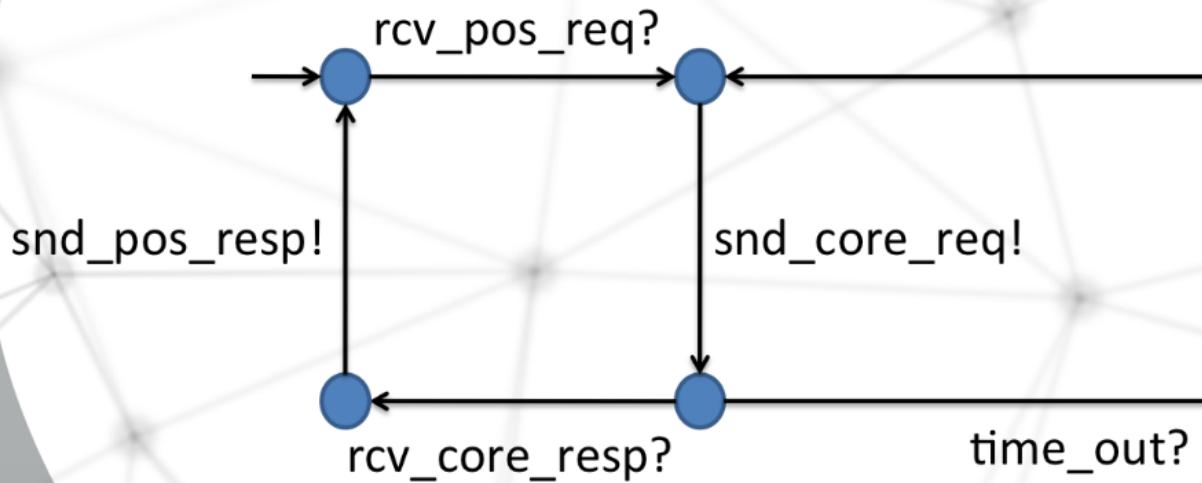
# Conformance Testing



IOCO Test-Cases



# Input-Output Transition Systems



? : input  
! : output  
tau : internal

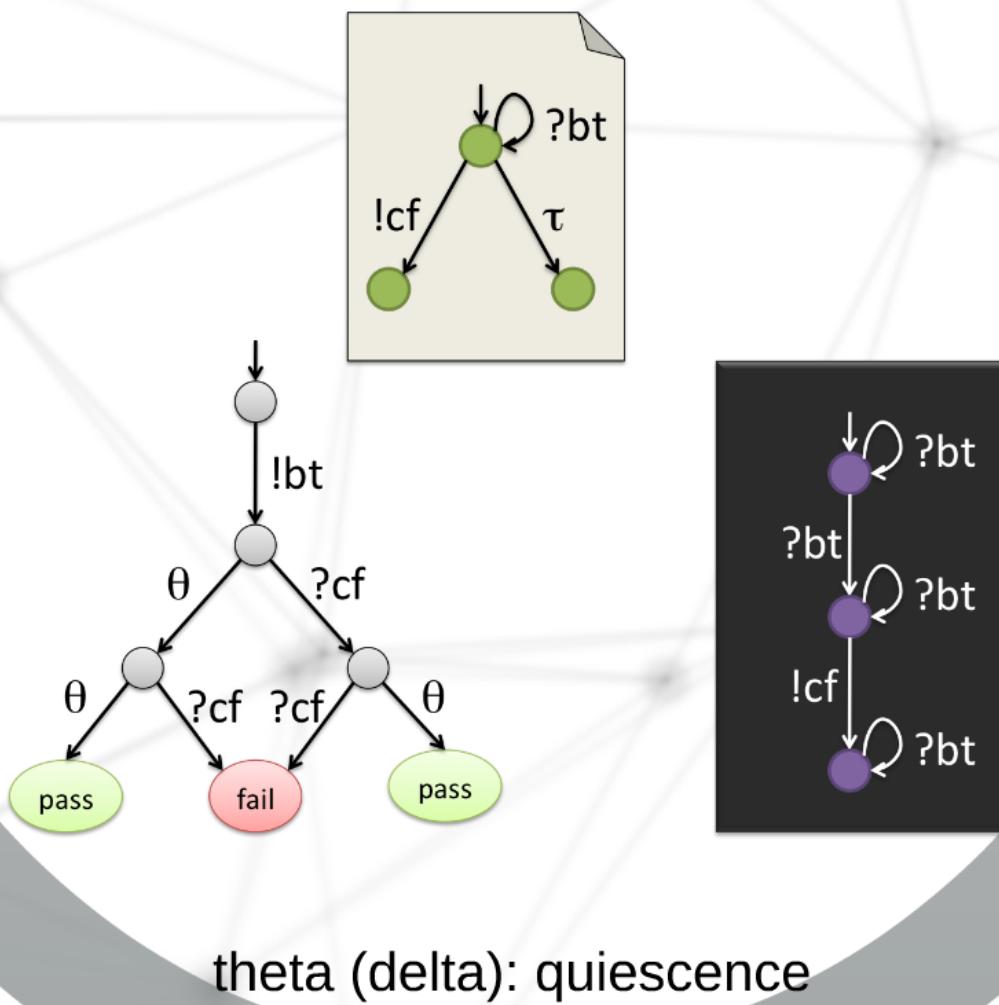
## IOCO (Put Informally)

imp ioco spec when

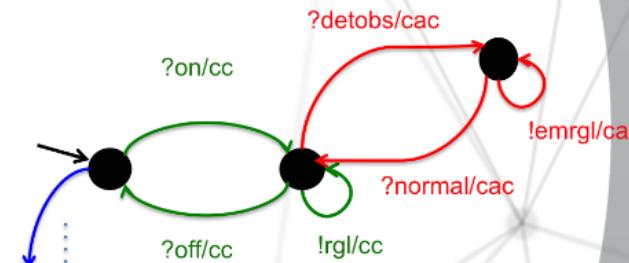
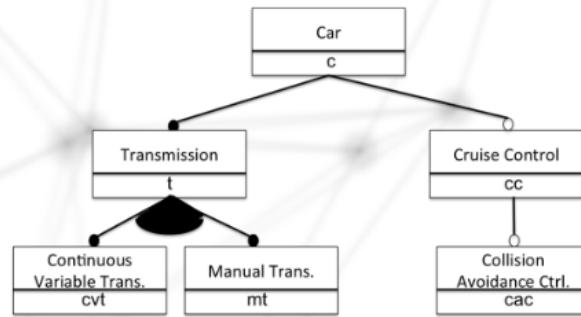
for each trace **t** of **spec**:

out(**imp after t**) subset out(**spec after t**)

# IOCO Test-Cases



# Modeling Software Product Lines



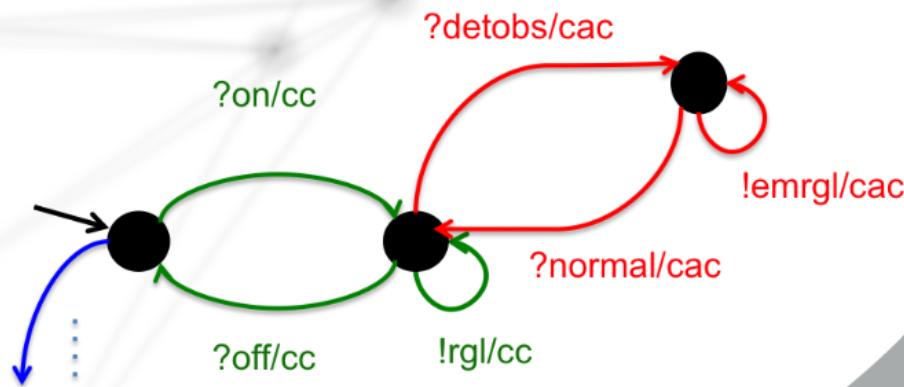
Product Derivation

$$\frac{\pi_1, \lambda \vdash (\gamma(s, a, s') \wedge \varphi)}{\Delta_\varphi(s) \hookrightarrow_{\text{derivation}} \gamma(s, \Delta_\varphi(s'))} \quad (1)$$

$$\frac{\pi_0, \lambda \vdash (\gamma(s, a, s') \wedge \varphi) \wedge a \in A_0 \cup \{\tau\}}{\Delta_\varphi(s) \xrightarrow{a} \Delta_\varphi(s')} \quad (2)$$

# Input Output Featured Transition Systems

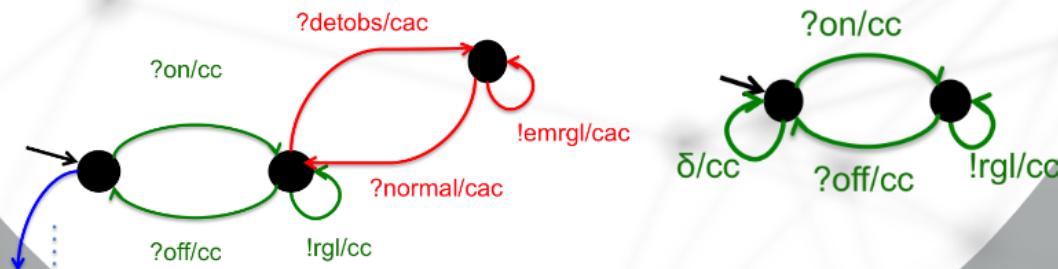
Feature diagrams (valid products) +  
Input-Output Transition Systems +  
Propositional annotations (features)



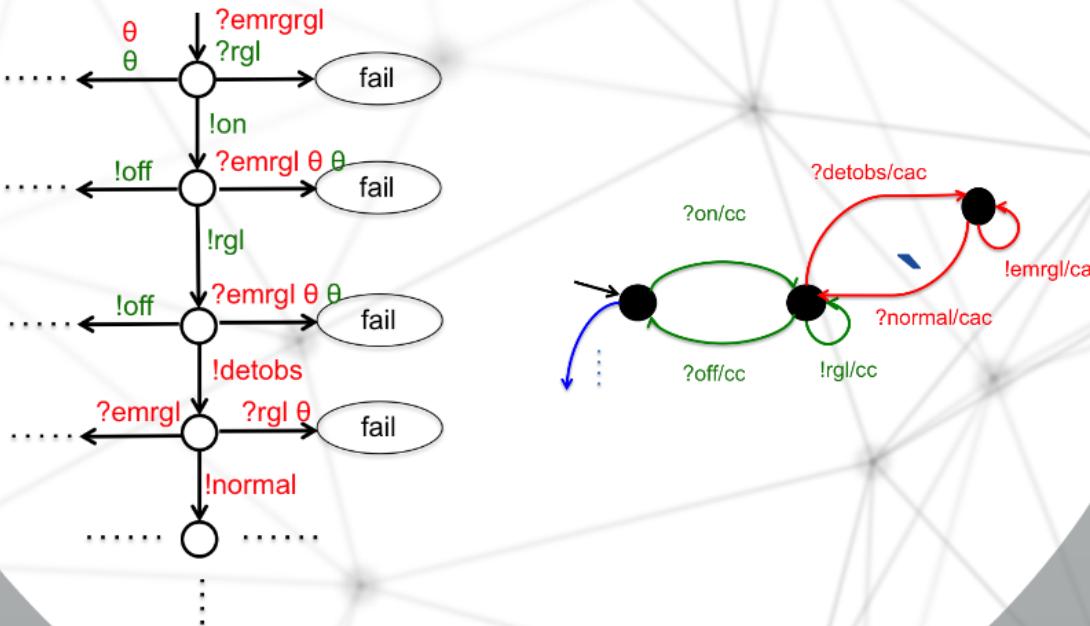
# Product Derivation

$$\frac{\exists_{\lambda} \lambda \models (\gamma(s, a, s') \wedge \varphi)}{\Delta_{\varphi}(s) \xrightarrow{a} \gamma(s, a, s') \wedge \varphi \Delta_{\varphi}(s')} \quad (1)$$

$$\frac{\nexists_{\lambda, s', a} \lambda \models (\gamma(s, a, s') \wedge \varphi) \wedge a \in A_O \cup \{\tau\}}{\Delta_{\varphi}(s) \xrightarrow{\delta} \varphi \Delta_{\varphi}(s)} \quad (2)$$



# Conformance Testing for Software Product Lines

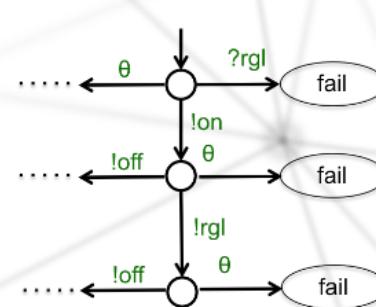
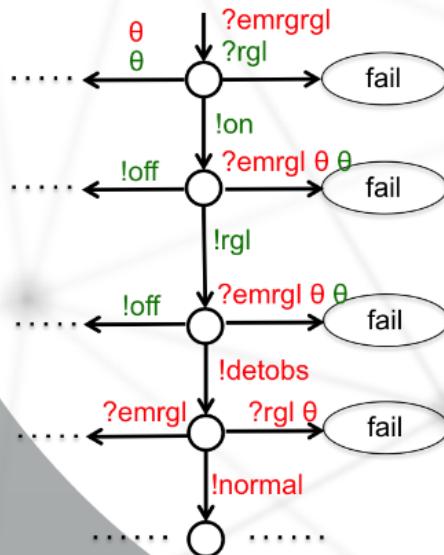


Click!

# Test-Suite Derivation

$$\frac{X, Y \neq \emptyset}{(X, \sigma), (Y, \sigma a) \in \mathbf{X}_s^\varphi} \quad (1) \quad \frac{a \in A_O \cup \{\theta\}}{(X, \sigma) \xrightarrow{a} \varphi (Y, \sigma')} \quad (3) \quad (4)$$

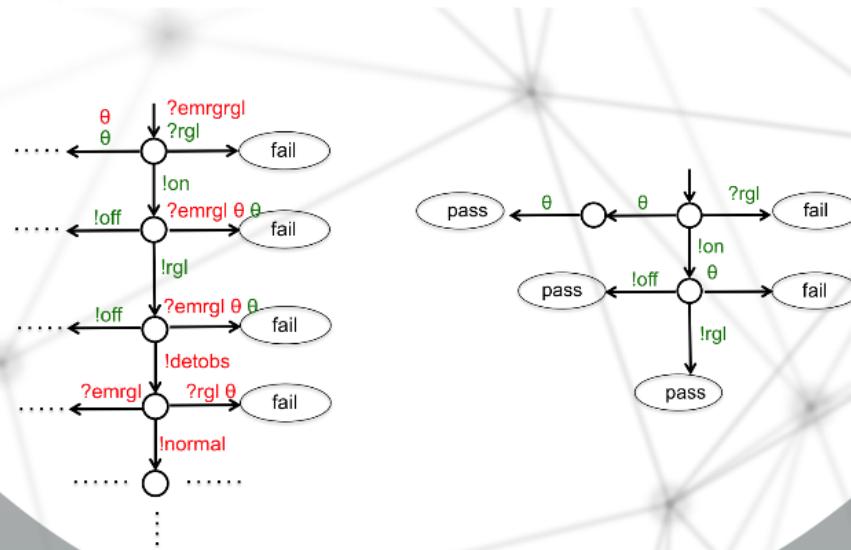
$$\frac{(X, \sigma) \not\xrightarrow{\varphi} \text{pass}}{(X, \sigma) \xrightarrow{a} \varphi \text{ fail}} \quad (5) \quad \frac{a \in A_O \cup \{\theta\}}{\begin{array}{l} \text{pass} \xrightarrow{a} \varphi \text{ pass} \\ \text{fail} \xrightarrow{a} \varphi \text{ fail} \end{array}} \quad (6)$$



# From Test-Suites to Test-Cases

$$\frac{(X, \sigma) \xrightarrow{a} \varphi (Y, \sigma') \wedge |\sigma'| < n}{t_n(X, \sigma) \xrightarrow{a} t_n(Y, \sigma')} \quad (7)$$

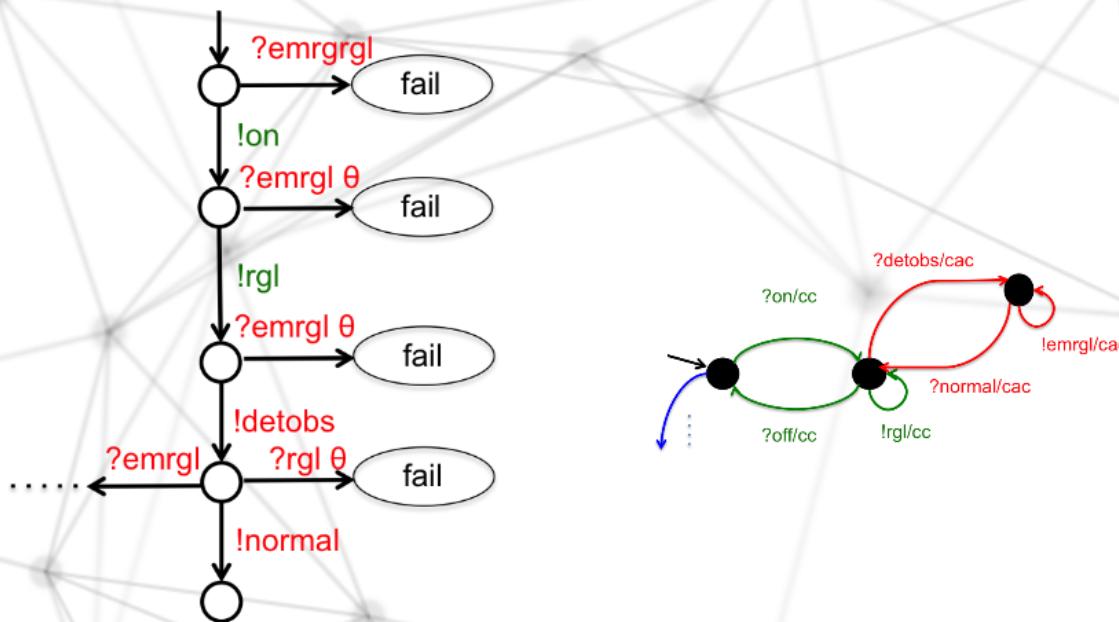
$$\frac{(X, \sigma) \xrightarrow{a} \mathcal{Y} \wedge (\mathcal{Y} = \text{pass} \vee \mathcal{Y} = \text{fail})}{t_n(X, \sigma) \xrightarrow{a} \mathcal{Y}} \quad (8)$$



# Click!

$$\begin{array}{ccc} \Delta_\varphi(s) & \xrightarrow{\text{test generation}} & (\hat{\mathbf{X}}_s, \varepsilon) \\ \Delta_{\varphi'}(-) \downarrow & & \downarrow \Delta_{\varphi'}^t(-) \\ \Delta_{\varphi \wedge \varphi'}(s) & \xrightarrow{\text{test generation}} & (\hat{\mathbf{X}}_s^{\varphi \wedge \varphi'}, \varepsilon) \cong \Delta_{\varphi'}^t(\hat{\mathbf{X}}_s, \varepsilon) \end{array}$$

# Spinal Test Suites



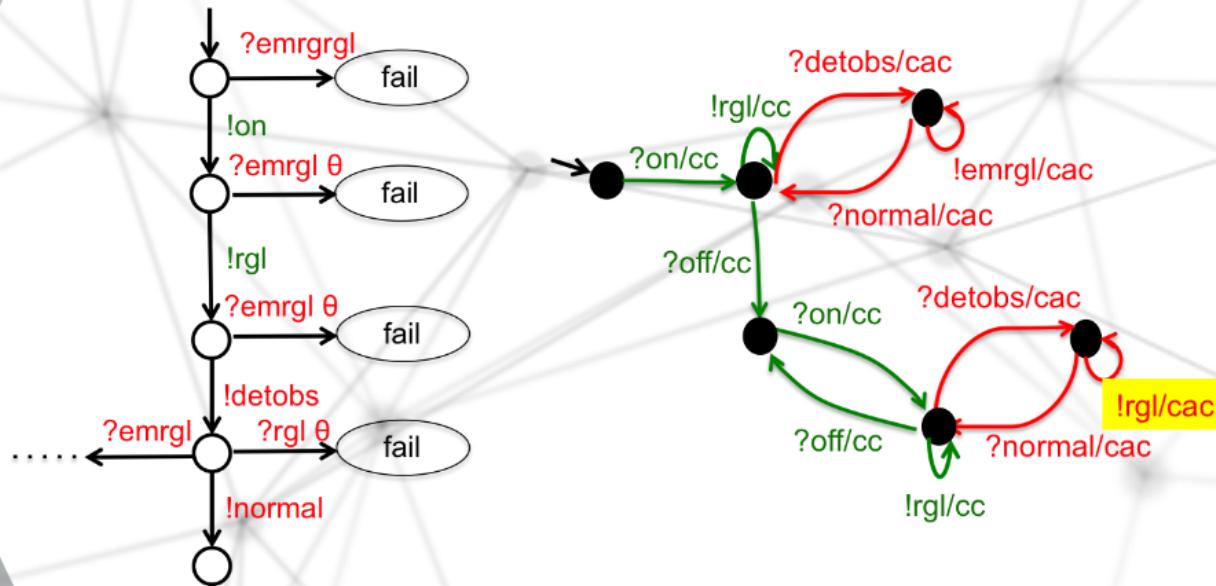
Spines: Simple paths through  
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# Inexhaustiveness



## Recovering exhaustiveness

- Orthogonal implementations:  
old features do not turn new  
features on/off at will
- Theorem: Spinal test suites are  
exhaustive for orthogonal  
implementations

# Future Work

- Coordinating the test process
- Efficient algorithms (reachability analysis, SMT solving)
- Tool support

# Thank You!

For more information please see:

- H. Beohar and M.R. Mousavi. Input-Ouput Conformance Testing Based on Feature Transition Systems, ACM SAC-SVT 2014.
- H. Beohar and M.R. Mousavi. Spinal Conformance Testing for Software Product Lines. MBT 2014.

**[m.r.mousavi@hh.se](mailto:m.r.mousavi@hh.se)**

# Fourth Halmstad Summer School on Testing

June 9 – June 12, 2014

Halmstad University, Sweden

[http://ceres.hh.se/mediawiki/index.php/HSST\\_2014](http://ceres.hh.se/mediawiki/index.php/HSST_2014)



## Tutorials

Automated Test Generation via Satisfiability Modulo Theory Solvers  
(Thomas Ball, Microsoft Research)

Model-Based Testing, the Difference between Theory and Practice  
(Machiel van der Bijl, Axini BV)

Improved Testing of Multithreaded Programs with Dynamic Symbolic Execution  
(Keijo Heljanko, Aalto University)

Property-Based Testing with QuickCheck  
(John Hughes, QuviQ and Chalmers)

Testing and Verifying Software Properties with ACL2 and ProofPad  
(Rex Page, University of Oklahoma)

Practical Model-Based Testing With Papyrus and RT-Tester  
(Jan Peleska, Verified International GMBH and Bremen University)

Model-Based Testing - There is Nothing More Practical than a Good Theory  
(Jan Tretmans, Radboud University Nijmegen and TNO - ESI)

## Organizers

Veronica Gaspes  
(Organization Chair, veronica.gaspes@hh.se)

Mohammad Mousavi  
(Program Co-Chair, m.r.mousavi@hh.se)

Eva Nestius  
(Local Organization)

Walid Taha  
(Program Co-Chair, walid.taha@hh.se)

## Registration

The registration deadline is April 15, 2014.

For more information, please check the school web page, or contact one of the organizers.



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